Journal of the Formosan Medical Association (2015) 114, 1225–1232

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.jfma-online.com

ORIGINAL ARTICLE

Modified expansive open-door laminoplasty technique improved postoperative neck pain and cervical range of motion

Kuang-Ting Yeh [a,b], Ing-Ho Chen [b,c], Tzai-Chiu Yu [b,c], Kuan-Lin Liu [b], Cheng-Huan Peng [b], Jen-Hung Wang [d], Ru-Ping Lee [a,e], Wen-Tien Wu [a,b,c,*,e]

[a] *Institute of Medical Sciences, Tzu Chi University, Hualien, Taiwan*
[b] *Department of Orthopedics, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan*
[c] *School of Medicine, Tzu Chi University, Hualien, Taiwan*
[d] *Department of Research, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Hualien, Taiwan*

Received 14 May 2014; received in revised form 8 October 2014; accepted 16 October 2014

KEYWORDS
C5 palsy;
minimally invasive surgical method;
modified expansive open-door laminoplasty;
multiple-level cervical spondylotic myelopathy;
postoperative axial neck pain

Background/Purpose: Expansive open-door laminoplasty (EOLP) is a useful technique for multiple-level cervical spondylotic myelopathy. The common postoperative complications of EOLP include moderate to severe neck pain, loss of cervical lordosis, decrease of cervical range of motion, and C5 palsy. We modified the surgical technique to lessen these complications. This study is aimed to elucidate the efficacy of modified techniques to lessen the complications of traditional procedures.
Methods: We collected data from 126 consecutive patients treated at our institution between August 2008 and December 2012. Of these, 66 patients underwent conventional EOLP (CEOLP) and the other 60 patients underwent modified EOLP (MEOLP). The demographic and preoperative data, axial pain visual analog scale scores at 2 weeks and 3 months postoperatively, clinical outcomes evaluated using Nurick score and Japanese Orthopedic Association recovery rate at 12 months postoperatively, and radiographic results assessed using plain films at 3 months and 12 months postoperatively for both groups were compared and analyzed.
Results: There were no significant differences regarding the preoperative condition between the CEOLP and MEOLP groups ($p > 0.05$). The Japanese Orthopedic Association recovery rate of the MEOLP group was 70.3%, comparable to the result of the other group (70.2%). Postoperative axial neck pain, loss of range of motion, and loss of lordosis of cervical curvature

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

* Corresponding author. Department of Orthopedics, Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Number 707, Zhongyang Road, Section 3, Hualien 970, Taiwan.
E-mail address: wentien2003@yahoo.com.tw (W.-T. Wu).
[e] Wen-Tien Wu and Ru-Ping Lee contributed equally to this article.

http://dx.doi.org/10.1016/j.jfma.2014.10.005

decreased significantly in the MEOLP group ($p < 0.05$). The complications of temporary C5 nerve palsy found in the CEOLP group did not exist in the MEOLP group.
Conclusion: MEOLP is a minimally invasive surgical method to treat multiple-level cervical spondylotic myelopathy, which decreases postoperative complications effectively.

Introduction

The natural course of multiple-level cervical spondylotic myelopathy (MCSM) is characterized by a slow, stepwise decline in function. Without surgical intervention, only 30—50% of MCSM patients are expected to stabilize.[1] Expansive open-door laminoplasty (EOLP) is a useful technique for enlarging the spinal canal area for spinal cord decompression, by retaining the dorsal elements of the cervical spine for support, and preventing invasion of the postlaminectomy membrane.[2] Previous research showed that the use of titanium miniplates to augment the EOLP procedure is efficient in treating MCSM.[3] Several postoperative complications of EOLP have been reported: axial neck pain,[4] loss of lordosis,[5] 4.7% mean incidence of C5 nerve palsy,[6] loss of neck range of motion (ROM),[7] and 34% lamina closure in patients who received EOLP without plates or spacers on the open sides.[8] The incidence of complications can be reduced either by reducing surgical dissection or by encouraging early neck extension exercise. The first part involves preserving the paraspinal musculature,[9] repairing the semispinalis cervicis (SC) attached to the C2 spinous process,[10] preserving the C7 spinous process,[11] and decreasing the violation of the facet joint.[12]

The overall Japanese Orthopedic Association (JOA) recovery rate following EOLP is approximately 50%.[13] In our initial series of EOLP (conventional EOLP or CEOLP), although we had comparable neurologic recovery outcomes, similar complications were also observed.[14] Approximately 50% of CEOLP patients presented moderate to severe postoperative axial neck pain, and the mean loss of neck ROM was 35%. To reduce the occurrence of these complications, we implemented a modified EOLP (MEOLP) procedure. This study was conducted to compare the surgical results of CEOLP and MEOLP.

Materials and methods

Study population

This retrospective study was conducted after receiving approval from the Research Ethics Committee of Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation (IRB101-100), Hualien, Taiwan. We modified the CEOLP procedures from April 2011. We collected the data of 66 consecutive cases that had undergone CEOLP from August 2008 to March 2011, and 60 consecutive cases that had undergone MEOLP from April 2011 to December 2012. The inclusion criteria were as follows: (1) positive myelopathic signs and symptoms, such as increased tendon reflexes in the extremities, clumsiness in the hands, and impaired toe-to-heel tandem gait; and (2) C3—7 stenosis. The exclusion criteria included the following: (1) existence of segmental instability, local kyphosis, or major anterior pathology; (2) a history of cervical spinal surgery; and (3) presence of myelopathy caused by spinal cord injuries, tumors, or infections. All 126 patients were diagnosed with MCSM based on clinical symptoms and magnetic resonance imaging (MRI) results, and had undergone surgery once. The follow-up duration was at least 12 months.

Surgical procedure

For CEOLP, the conventional laminoplasty technique used in our study had been reported previously and is briefly described here.[14] The bilateral paraspinal musculatures were dissected and gutters were created at the laminofacet junctions. The C3—7 laminae were elevated and then secured using five titanium miniplates. For the MEOLP, after the unilateral paraspinal musculature was dissected (Fig. 1A), we cut down the C3—6 spinous process to approach to the other side with an angled saw (Fig. 1B). Bilateral gutters were created medially without violating the facet joints. C7 partial laminectomy was performed (Fig. 1C), and C3—6 laminae were then elevated and secured using four titanium miniplates. In both the procedures, the SC was carefully detached from the C2 spinous process and then reattached using stout sutures. In the modified procedure, the hinge-side SC was less detached. Fig. 2 shows finished pictures of both procedures.

Outcome measurement

The clinical and radiographic aspects of the surgical outcomes are detailed as follows. The clinical outcomes were assessed based on the JOA, Nurick, and visual analogue scale (VAS) scores. We evaluated the JOA recovery rates at 12 months following surgery using the following formula: (12-month JOA score - preoperative JOA scores)/(17 - preoperative JOA score) × 100%. Axial neck pain was evaluated based on the VAS scores at 2 weeks and 3 months following surgery. Complications were also recorded.

The radiographic outcomes were evaluated based on the Pavlov ratio (canal—body ratio), cervical curvature (i.e., the lordotic angle between the lower edge of C2 and the upper edge of C7 at true lateral plain films), and ROM (i.e., the difference in the cervical curvature on maximal flexion—extension lateral radiographical view). The loss rates of cervical curvature and ROM were evaluated using the following formulas:

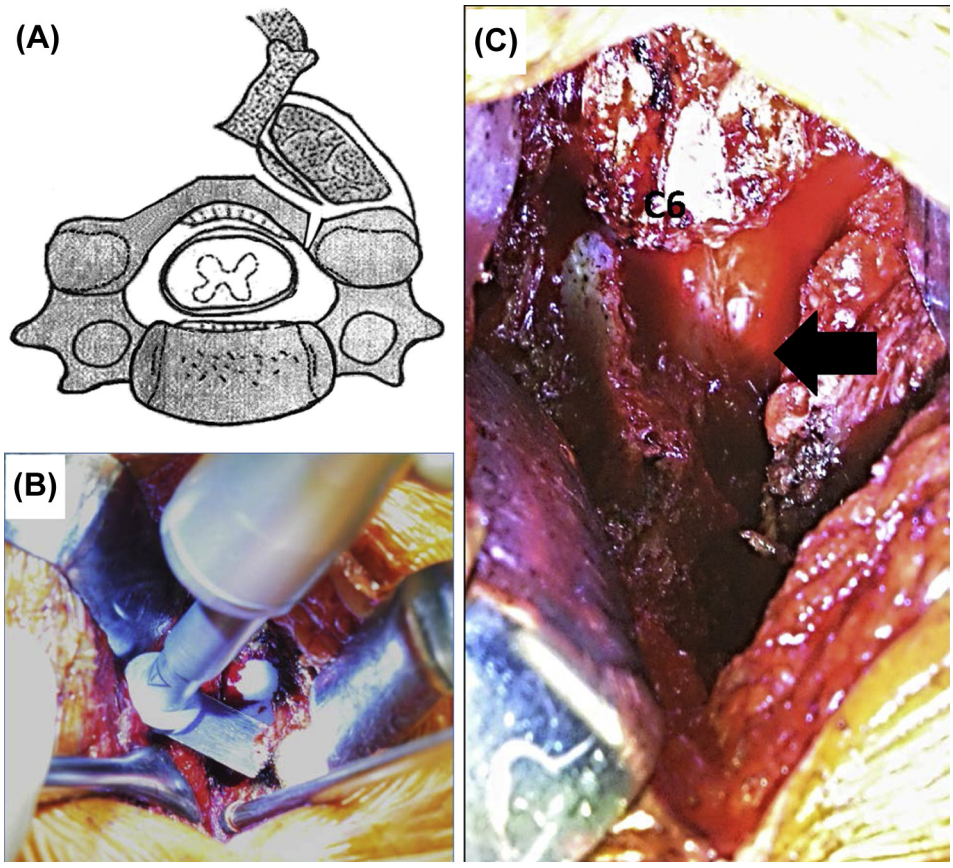

Figure 1 (A, B) Unilateral approach for bilateral dissections with an angled saw. (C) C7 partial laminectomy (black arrow) instead of laminoplasty for adequate decompression and nuchae muscle attachment preservation.

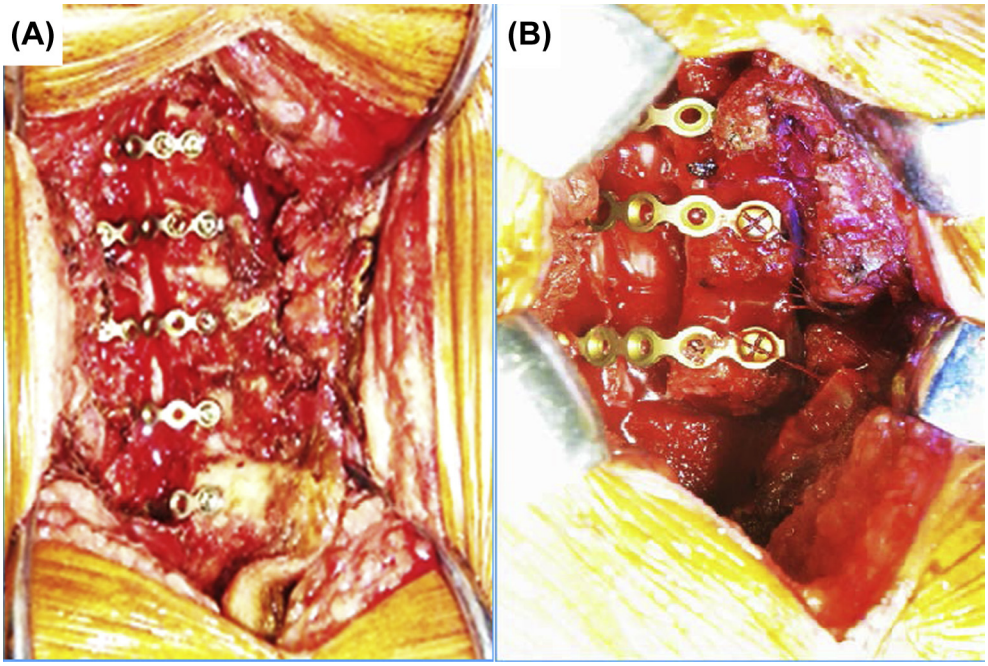

Figure 2 Intraoperative final pictures of (A) conventional and (B) modified expansive open-door laminoplasty. Lesser dissection is noted in the picture of modified techniques.

Proportion of cervical curvature lordotic angle loss (loss of lordosis, %) = (preoperative cervical curvature - postoperative cervical curvature)/(preoperative cervical curvature) × 100%

Proportion of ROM loss (loss of ROM, %) = (preoperative ROM - postoperative ROM)/(preoperative ROM) × 100%

Cervical plain X-rays (various views) were taken pre- and postoperatively, and again at 3 months, 6 months, and 12 months following surgery. Changes in the Pavlov ratio, cervical curvature, and ROM were measured independently by two orthopedic doctors, using X-rays. MRI and computed tomography were, respectively, performed at 12 months and 6 months following surgery.

Comparative analysis

Data are presented as the mean ± standard deviation. An independent *t* test was used to analyze the difference between pre- and postoperative scores, as well as between the CEOLP and MEOLP groups. Fisher's exact test was used to analyze the incidence of C5 palsy between the two groups. A *p* value of <0.05 was considered statistically significant.

Results

The baseline characteristics of the two groups did not differ significantly (Table 1). The mean operation time of CEOLP was 105 minutes and that of MEOLP was 75 minutes. The average blood loss volumes of CEOLP and MEOLP were 225 mL and 125 mL, respectively. The mean wound length of MEOLP was 5.3 cm and that of CEOLP was 7.7 cm (Fig. 3).

Table 1 Baseline characteristics and preoperative data of the two groups.

Items	CEOLP (mean ± SD) (n = 66)	MEOLP (mean ± SD) (n = 60)	t value	p
Level of CSM	5	5	—	—
Age (y)	61.2 ± 12.3	60.6 ± 11.6	0.237	0.813
Male (%)	71.2	70.0	0.032	0.904
Myelomalacia (%)	33.3	26.7	0.713	0.514
Symptom duration time (mo)	14.6 ± 15.0	11.6 ± 11.9	0.985	0.327
JOA score	10.0 ± 3.0	9.9 ± 2.8	0.056	0.955
Nurick score	3.5 ± 1.1	3.3 ± 1.2	0.698	0.487
Neck VAS	5.0 ± 2.1	4.9 ± 1.3	0.252	0.801
Pavlov ratio	0.7 ± 0.1	0.7 ± 0.0	1.377	0.172
cervical curvature (degree)	10.9 ± 8.9	14.0 ± 10.7	−1.498	0.137
ROM (degree)	25.0 ± 12.4	23.2 ± 10.2	0.709	0.480

CEOLP = conventional expansive open-door laminoplasty; CSM = cervical spondylotic myelopathy; JOA = Japanese Orthopedic Association; MEOLP = modified expansive open-door laminoplasty; ROM = range of motion; SD = standard deviation; VAS = visual analog scale.

Functional outcome

For the CEOLP group, the mean 12-month postoperative JOA score, JOA recovery rate, and Nurick score were 14.6 ± 2.4 (Table 2), 70 ± 22%, and 1.3 ± 1.5, respectively. For the MEOLP group, the mean 12-month postoperative JOA and Nurick scores were 14.6 ± 2.3 and 1.3 ± 1.5, respectively, and the mean JOA recovery rate was 70% ± 20%. Both groups had favorable functional recovery.

Two weeks after surgery, the mean neck VAS scores were 6.4 ± 1.2 and 5.5 ± 1.0 for the CEOLP and MEOLP groups, respectively ($p < 0.05$) (Table 2). Three months following surgery, the mean neck VAS scores were 3.1 ± 2.3 and 2.1 ± 1.6 for the CEOLP and MEOLP groups, respectively ($p < 0.05$). Postoperative axial neck pain significantly decreased in the MEOLP group.

Radiographic outcome

On Day 1 following surgery, the Pavlov ratios were 1.1 ± 0.1 and 1.1 ± 0.1 in the CEOLP and MEOLP groups, respectively (Table 3). At 12 months following surgery, these scores were maintained in both groups, which were significantly increased compared with the preoperative scores ($p < 0.05$) and were nearly identical. At 3 months following surgery, both cervical curvature and ROM had decreased and were partially restored at 12 months following surgery in both groups. The 12-month postoperative cervical curvature was significantly more lordotic in the MEOLP group than in the CEOLP group ($p < 0.05$). Loss of ROM was also significantly less in the MEOLP group than in the CEOLP group ($p < 0.05$). The 12-month postoperative MRI showed lesser fibrosis of the right-side paraspinal muscles in the MEOLP group than in the CEOLP group (Fig. 4). The 6-month postoperative computed tomography results revealed favorable union over the osteotomied sites, but the more medial gutters with better reservation of the facet joints were noted in the MEOLP group (Fig. 5)

Postoperative complications

The complication rates of both groups are shown in Table 4. Axial neck pain was defined as a neck pain VAS score of ≥ 4 at 3 months postoperatively. The MEOLP group had smaller ratios of axial neck pain, loss of lordosis, and loss of ROM than the CEOLP group. The complication of C5 palsy was noted in three patients (4.5%) of the MEOLP group, all of whom recovered well after 3 months following surgery. No case of C5 palsy was observed in the MEOLP group. There were no cases of lamina reclosure in both groups.

Discussion

In this study, we modified the CEOLP by minimizing the number of surgical dissections to reduce the complication rate. A comparison of the JOA recovery rate and the improved Nurick scores shows that both CEOLP and MEOLP

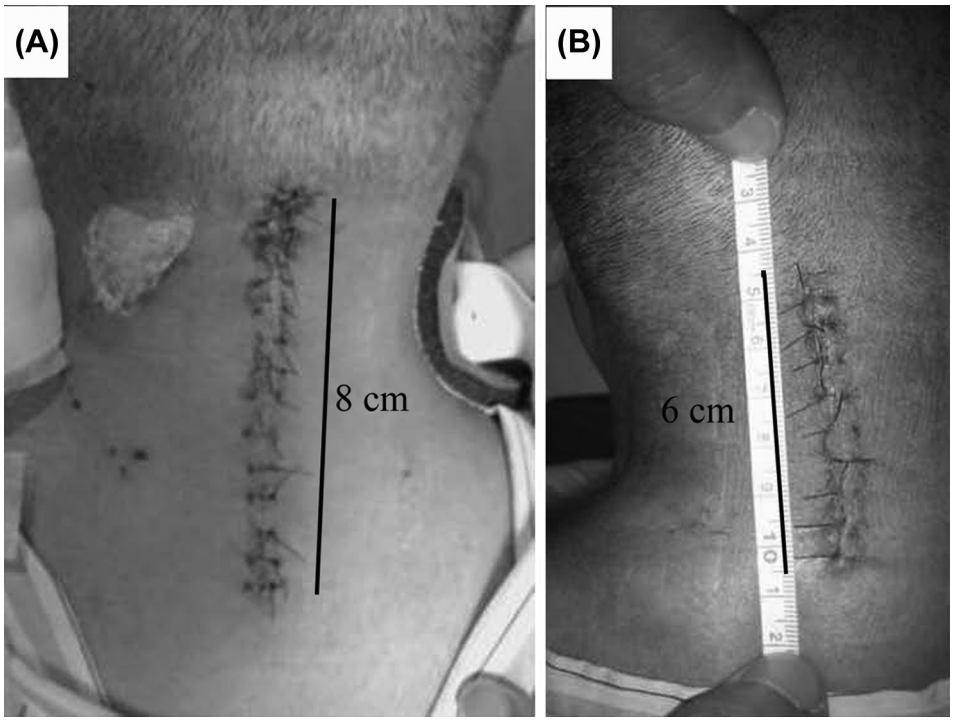

Figure 3 Postoperative wounds of (A) CEOLP and (B) MEOLP. Mean wound lengths of MEOLP and CEOLP are 5.3 cm and 7.7 cm, respectively. CEOLP = conventional expansive open-door laminoplasty; MEOLP = modified expansive open-door laminoplasty.

were effective in treating MCSM. The Pavlov ratio, which represents the spinal canal width, increased equally in both groups and remained stable over 1 year, indicating that MEOLP could provide a spinal canal enlargement effect that is comparable with that obtained through CEOLP.

Axial neck pain is the most common problem following laminoplasty. The incidence reported in the literature was 30–60%.[4] Yoshida et al[15] indicated that by decreasing the destruction of paraspinal muscle and reattaching both the spinous process and the extensor musculature, the occurrence of muscle fibrosis and postoperative axial pain could be decreased effectively. Takeuchi et al[10] suggested that failure to repair the SC could cause significant axial neck pain and loss of lordosis. They showed that the opening angle of the C2 spinous process is smaller in men than in women, and the insertion width is narrower than the width of the spinous process spacers that are used commonly in laminoplasty studies using cadavers. In a prospective study on reducing axial neck pain, Hosono et al[16] showed that preserving the C7 spinous process as the main insertion of ligamentum nuchae was more crucial than preserving the deep extensor musculature. The ratios of neck pain at early and late stages were significantly less in a C3–6 laminoplasty than in a C3–7 laminoplasty.[17] Our modified procedure involved preserving the unilateral paraspinal musculature, reattaching the SC, and preserving the C7 spinous process. Furthermore, surgical results show significant improvements in postoperative neck pain at 2 weeks and 3 months following surgery, and improved cervical lordosis at 12 months following surgery.

The incidence of C5 nerve palsy in the literature[6] is approximately 4.7%. The cause of the palsy was multifactorial, showing that excessive expansion by laminoplasty should be avoided to prevent the C5 nerve root from becoming tented by a posterior shift of the spinal cord. Spontaneous recovery of deltoid muscle power is expected, but motor paralysis and pain in the upper extremity may cause discomfort to patients for a long period. Creating symmetrical gutters medially can decrease excessive C5 nerve root traction injury with the same effect of spinal

Table 2 Functional recovery of the two groups.

Functional score	CEOLP (mean ± SD)	MEOLP (mean ± SD)	*t* value	*p*
Preop JOA score	10.0 ± 3.0	9.9 ± 2.8	0.056	0.955
Postop JOA score	14.6 ± 2.4	14.6 ± 2.3	−0.169	0.867
JOA recovery rate	0.7 ± 0.2	0.7 ± 0.2	−0.029	0.977
Preop Nurick score	3.5 ± 1.1	3.3 ± 1.2	0.698	0.487
Postop Nurick score	1.3 ± 1.5	1.3 ± 1.5	0.019	0.985
Postop VAS (2 wk)	6.4 ± 1.2	5.5 ± 1.0	3.914	0.000*
Postop VAS (3 mo)	3.1 ± 2.3	2.1 ± 1.6	2.547	0.013*

*$p < 0.05$.
CEOLP = conventional expansive open-door laminoplasty; JOA = Japanese Orthopedic Association; MEOLP = modified expansive open-door laminoplasty; SD = standard deviation; VAS = visual analog scale.

Table 3 Radiographic outcomes of the two groups.

Items	CEOLP (mean ± SD)	MEOLP (mean ± SD)	*t* value	*p*
Pavlov ratio				
Preop	0.7 ± 0.1	0.7 ± 0.1	1.377	0.172
Postop 1 (d)	1.1 ± 0.1	1.1 ± 0.1	0.713	0.477
Postop 12 (mo)	1.1 ± 0.1	1.1 ± 0.1	0.423	0.673
Postop 12 (mo)−preop	0.5 ± 0.0	0.5 ± 0.1	−0.092	0.927
Cervical curvature (degree)				
Preop	10.9 ± 8.9	14.0 ± 10.7	−1.498	0.137
Postop 3 (mo)	4.0 ± 10.3	6.2 ± 9.4	−1.016	0.312
Postop 12 (mo)	5.7 ± 8.9	10.0 ± 9.5	−2.129	0.036*
Postop 12 (mo)−preop	−6.9 ± 10.3	−7.8 ± 8.2	0.422	0.674
ROM (degree)				
Preop	25.0 ± 12.4	23.2 ± 10.2	0.709	0.480
Postop 3 (mo)	14.0 ± 7.6	15.5 ± 6.9	−0.970	0.334
Postop 12 (mo)	17.4 ± 7.5	18.5 ± 7.3	−0.657	0.513
Postop 12 (mo)−preop	−11.1 ± 6.7	−7.7 ± 4.1	−2.586	0.011*

*$p < 0.05$.
CEOLP = conventional expansive open-door laminoplasty; MEOLP = modified expansive open-door laminoplasty; ROM = range of motion; SD = standard deviation.

canal widening and cord decompression.[18] According to Fujiwara et al[19], the transverse area of the spinal cord was greatest at the C5 segment and the transverse diameter was <14 mm. Therefore, gutters can be created only approximately 7 mm from the midline at both open and hinge sides, which are more medial to the facet joints, to adequately decompress the spinal cord. Other advantages of cutting the edges medially include preventing excessive

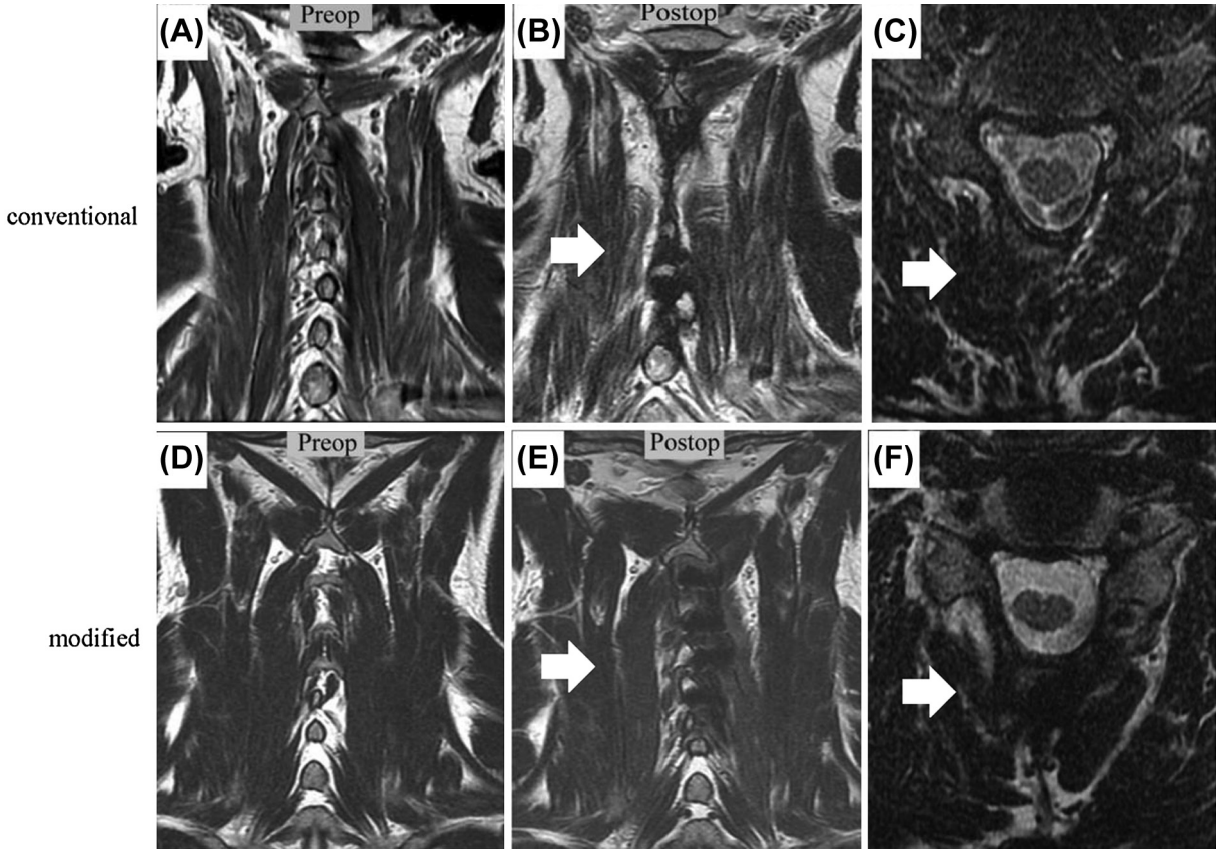

Figure 4 T2-weighted MRI of (A–C) conventional (A, B as coronal view; C as postoperative axial view) and (D–F) modified (D, E as coronal view; F as postoperative axial view) expansive open-door laminoplasty at 12 months pre-/postoperatively. Lesser right-side paraspinal muscle (white arrow) fibrosis is noted in the picture of modified techniques after operation. MRI = magnetic resonance imaging.

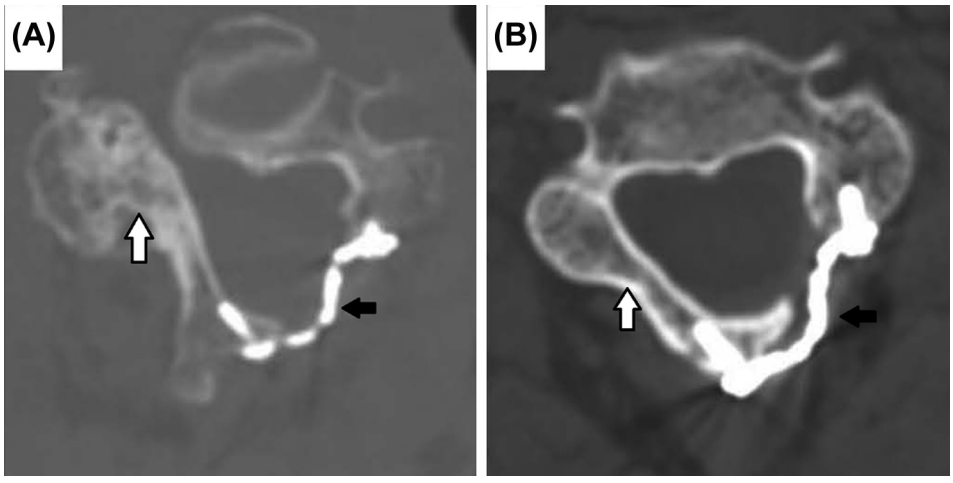

Figure 5 Axial computed tomography scans of (A) conventional and (B) modified expansive open-door laminoplasty at 6 months postoperatively. Both pictures reveal hinge-side good union and well-positioned titanium miniplates and screws without any loosening (black arrow). More medial gutter (white arrow) is noted in the picture of modified techniques.

violation of the facet joints. Overdissection of the lateral-third aspect of the lateral mass can easily damage the posterior ramus of the spinal nerve. This can cause paraspinal muscle atrophy, which is a leading cause of axial pain, kyphosis, and loss of ROM.[20] In this study, we created a more medial gutter and prevented violation of the facet joints in the MEOLP procedure. Both these outcomes contributed to zero incidences of C5 nerve palsy and a significant improvement in the loss of ROM, compared with the CEOLP outcomes.

The results of this study are limited because of the small number of MEOLP cases with a short-term follow up and the retrospective design. The method of measuring cervical ROM is also one of our limitations due to the possibility of estimation errors. Cervical movements are multidirectional motions, but our radiographical outcome analysis of ROM focused only on one plane. Rotational and lateral bending motions were not estimated. In addition, the late effects of muscle preservation on ROM and cervical curvature may require a longer period of follow up.[21,22] In future, we intend to perform additional evaluations of this effective procedure.

Conclusion

MEOLP appears to be a minimally invasive and effective surgical procedure for treating MCSM. The use of various methods to reduce the number of required surgical dissections can reduce postoperative axial pain and loss of ROM. The anticipated benefits of the modified procedure include preservation of cervical lordosis and a decrease in the incidence of postoperative C5 nerve palsy. Future studies should include more patients and have a longer postoperative follow-up period.

Table 4 Complication rates of the two groups.

Complication	CEOLP	MEOLP
Case of residual axial neck pain (%)	45	33.3
Case of C5 palsy (%)	4.5	0
Case of lamina reclosure (%)	0	0
Mean loss of lordotic angle (%)	26.3	19.6
Mean loss of ROM (%)	30	20

CEOLP = conventional expansive open-door laminoplasty; MEOLP = modified expansive open-door laminoplasty; ROM = range of motion.

References

1. Kadanka Z, Mareš M, Bednarík J, Smrcka V, Krbec M, Stejskal L, et al. Approaches to spondylotic cervical myelopathy: conservative versus surgical results in a 3-year follow-up study. *Spine (Phila Pa 1976)* 2002;**27**:2205—10.
2. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii Y. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine (Phila Pa 1976)* 1983;**8**:693—9.
3. O'Brien MF, Peterson D, Casey AT, Crockard HA. A novel technique for laminoplasty augmentation of spinal canal area using titanium miniplate stabilization. A computerized morphometric analysis. *Spine (Phila Pa 1976)* 1996;**21**:474—83. discussion 484.
4. Cho CB, Chough CK, Oh JY, Park HK, Lee KJ, Rha HK. Axial neck pain after cervical laminoplasty. *J Korean Neurosurg Soc* 2010;**47**:107—11.
5. Ratliff JK, Cooper PR. Cervical laminoplasty: a critical review. *J Neurosurg* 2003;**98**:230—8.
6. Sakaura H, Hosono N, Mukai Y, Ishii T, Yoshikawa H. C5 palsy after decompression surgery for cervical myelopathy: review of the literature. *Spine (Phila Pa 1976)* 2003;**28**:2447—51.
7. Hyun SJ, Riew KD, Rhim SC. Range of motion loss after cervical laminoplasty: a prospective study with minimum 5-year follow-up data. *Spine J* 2013;**13**:384—90.
8. Matsumoto M, Watanabe K, Tsuji T, Ishii K, Takaishi H, Nakamura M, et al. Risk factors for closure of lamina after open-door laminoplasty. *J Neurosurg Spine* 2008;**9**:530—7.
9. Kato M, Nakamura H, Konishi S, Dohzono S, Toyoda H, Fukushima W, et al. Effect of preserving paraspinal muscles on postoperative axial pain in the selective cervical laminoplasty. *Spine (Phila Pa 1976)* 2008;**33**:E455—9.
10. Takeuchi K, Yokoyama T, Aburakawa S, Itabashi T, Toh S. Anatomic study of the semispinalis cervicis for reattachment during laminoplasty. *Clin Orthop Relat Res* 2005;**436**:126—31.

11. Sakaura H, Hosono N, Mukai Y, Iwasaki M, Yoshikawa H. Medium-term outcomes of C3-6 laminoplasty for cervical myelopathy: a prospective study with a minimum 5-year follow-up. *Eur Spine J* 2011;**20**:928—33.
12. Liu J, Ebraheim NA, Sanford Jr CG, Patil V, Haman SP, Ren L, et al. Preservation of the spinous process—ligament—muscle complex to prevent kyphotic deformity following laminoplasty. *Spine J* 2007;**7**:159—64.
13. Wang MY, Green BA. Open-door cervical expansile laminoplasty. *Neurosurgery* 2004;**54**:119—23. discussion 123—4.
14. Yeh KT, Yu TC, Chen IH, Peng CH, Liu KL, Lee RP, et al. Expansive open-door laminoplasty secured with titanium miniplates is a good surgical method for multiple-level cervical stenosis. *J Orthop Surg Res* 2014;**9**:49. 1—11.
15. Yoshida M, Otani K, Shibasaki K, Ueda S. Expansive laminoplasty with reattachment of spinous process and extensor musculature for cervical myelopathy. *Spine (Phila Pa 1976)* 1992;**17**:491—7.
16. Hosono N, Sakaura H, Mukai Y, Yoshikawa H. The source of axial pain after cervical laminoplasty-C7 is more crucial than deep extensor muscles. *Spine (Phila Pa 1976)* 2007;**32**:2985—8.
17. Hosono N, Sakaura H, Mukai Y, Fujii R, Yoshikawa H. C3—6 laminoplasty takes over C3—7 laminoplasty with significantly lower incidence of axial neck pain. *Eur Spine J* 2006;**15**:1375—9.
18. Lee SE, Chung CK, Kim CH, Jahng TA. Symmetrically medial bony gutters for open-door laminoplasty. *J Spinal Disord Tech* 2013;**26**:E101—6.
19. Fujiwara K, Yonenobu K, Hiroshima K, Ebara S, Yamashita K, Ono K. Morphometry of the cervical spinal cord and its relation to pathology in cases with compression myelopathy. *Spine (Phila Pa 1976)* 1988;**13**:1212—6.
20. Seichi A, Kimura A, Higashi T, Endo T, Kojima M, Inoue H, et al. Localization of the medial branches of the cervical dorsal rami during cervical laminoplasty. *Spine (Phila Pa 1976)* 2012;**37**:E1603—6.
21. Kotani Y, Abumi K, Ito M, Sudo H, Takahata M, Ohshima S, et al. Minimum 2-year outcome of cervical laminoplasty with deep extensor muscle-preserving approach: impact on cervical spine function and quality of life. *Eur Spine J* 2009;**18**:663—71.
22. Kotani Y, Abumi K, Ito M, Sudo H, Takahata M, Nagahama K, et al. Impact of deep extensor muscle-preserving approach on clinical outcome of laminoplasty for cervical spondylotic myelopathy: comparative cohort study. *Eur Spine J* 2012;**21**:1536—44.